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POWER ASSISTANCE DEVICE FOR AN ULTRASONIC VIBRATION DENTAL HANDPIECE

The present invention relates to an electronic servo-control device for dental handpiece, of the type in which the vibration of a tool is obtained by means of a piezoelectric transducer.

It is known that a piezoelectric transducer generating ultrasound vibrations is, where possible, used in resonance so as to obtain maximum amplitudes and power of the vibrations. When such a transducer, to which a tool is mechanically coupled, comes into contact during a work phase with tissues of different natures, i.e. hard tissues, soft tissues, with or without the presence of a liquid, its resonant circuit evolves during the work. It is known that, in such a handpiece, the speed of vibration of the transducer is a direct function of the electric current which circulates therein and that the effort necessary for this vibration is a direct function of the supply voltage at the terminals of said transducer. It will be understood that, if it is desired that a handpiece operates with optimum yield, the vibrations of the transducer must correspond to the series resonance of this handpiece and, during work, the operational conditions must vary so as to remain in resonance.

According to the invention, the frequency will be tracked by observing the phase-shift which exists between the voltage and the

current supplied and by electrically compensating the intrinsic capacity of the transducer. Such an electric circuit is translated in series resonance by a low impedance and a zero phase-shift.

The present invention thus has for its object to propose such a device for servo-control of the piezoelectric transducer of a vibration generator for dental handpiece, adapted to operate permanently at series resonance frequency, whatever the nature of the tissues on which the tool with which this handpiece is equipped, operates.

The present invention thus relates to a device for servo-control of a dental handpiece activated by an ultrasound generator, comprising supply means of given frequency, characterized in that:

- it comprises two circuits, namely a work circuit to whose terminals the ultrasound generator is connected, and a control circuit,

- the work circuit comprises an inductance in parallel between its output terminals,

- the supply is adapted to deliver at the output a voltage in phase with a voltage which is delivered thereto on its input,

- the control circuit is constituted by an intensity transformer whose primary is arranged in series in the work circuit and whose secondary forms, with a capacitor and a resistor associated therewith, an RLC circuit of which the voltage at the terminals of the resistor is sent to the input of said

supply,

- the control circuit comprises means for varying the value of the capacitor and/or that of the self-induction coil of the secondary of the intensity transformer.

The secondary of the intensity transformer preferably comprises a core mobile inside its winding adapted to vary its inductance.

In a preferred embodiment, the supply means will be connected to the work circuit via a voltage transformer of which the inductances of the primary and of the secondary will be high.

In an interesting form of embodiment of the invention, the inductance arranged between the output terminals of the work circuit will be such that, with the intrinsic capacitance of the handpiece and the internal resistance thereof, an RLC circuit close to the resonance is formed.

A form of embodiment of the present invention will be described hereinafter by way of non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 schematically shows a frequency tracking device according to the invention.

Figure 2 schematically shows the phase-shifts between current and intensity in a circuit of the type shown in Figure 1.

Figure 3 is a curve representing the variation of the phase-shift between current and voltage in a circuit according to the invention as a function of a multiple of the

frequency.

Figure 4 is a curve representing the respective variations as a function of the frequency, of the power supplied to a specific handpiece and of the corresponding phase-shift between current and intensity.

The frequency tracking oscillator shown in Figure 1 is essentially constituted by a supply 1 capable of generating between its two output terminals A and B a voltage V_P which supplies the primary 3 of a voltage transformer T_1. One of the terminals C of the secondary 4 of this transformer is connected to an output S1 of the circuit to which an input E_1 of a handpiece 5 is connected. The other terminal D of this same secondary 4 is connected to the other output S2 of the circuit with the interposition of the primary 7 of a current transformer T_2. The second input E2 of the handpiece 5 is connected to the terminal S2. An inductance 9 of value L_s is arranged in parallel between the input terminals E_1 and E_2 of the handpiece 5.

As is shown in Figure 1, the secondary 11 of the intensity transformer T_2 is arranged in series with a capacitor 13 of value C_2 and a resistor 15 of value R_2, the latter representing the parasitic resistors of the RLC circuit thus formed.

The terminals G and H of the resistor 15 are connected to input terminals IJ of the supply 1.

There are thus two circuits, namely a work circuit which controls the handpiece 5 and a control circuit constituted by the RLC circuit.

The supply 1 is constituted so that the

voltage V_P produced on its output terminals A, B is in phase with the voltage V_r existing between its input terminals I and J.

Under these conditions, as schematically shown in Figure 2, for the oscillator constituted by the self-induction coil 11, the capacitor 13 and the resistor 15 to enter in oscillation, the signal of voltage V_r collected at the terminals of the resistor R_2 must be in phase with V_s, which condition is met if $\varphi 2 = - \varphi 1$. In effect, $\varphi 2$ and $\varphi 1$ represent the phase-shift between voltage and intensity respectively in the oscillating control RLC circuit and in the work circuit controlling the vibrations of the handpiece 5.

If the voltage V_r existing between the input terminals I and J of the supply 1 is expressed as a function of the current I_1 circulating in the primary 7 of the transformer T2, it will be noted that the current I_1 is delayed by $\varphi 1$ with respect to voltage V_s (or to voltage V_p) and that the voltage V_r is in phase with the current I_2.

If the equations of the transformer are taken into account, the following will be obtained by using the complex mathematical notification:

$$V_1 = Z_1 I_1 + jm\omega I_2 \text{ with } Z_1 = jL_1\omega \qquad (1)$$

$$0 = Z_2 I_2 + jm\omega I_1 \text{ with } Z_2 = R_2 + j(L_2\omega - 1/C_2\omega) \qquad (2)$$

m representing the coefficient of mutual inductance of one of the windings of the transformer on the other winding.

The transformer T_2 being an intensity transformer, it is possible, in known manner, to disregard the influence of the secondary winding on the primary winding so

that the expression $jm\omega I_2 = 0$ and the value of I_1 is drawn from equation (1), viz.:

$$I_1 = V_1 \ / \ jL_1\omega = -jV_1 \ / \ L_1\omega$$

By transferring this value in equation (2), the expression of the current I_1 in the work circuit as a function of the current I_2 in the RLC circuit is obtained, viz.:

$$I_1 = 1/m\omega \ (1/C_{1\omega}-L_{2\omega}+jR_2)\ I_2$$

Under these conditions, the phase-shift of the current I_2 with respect to current I_1 will be:

$$tg\varphi_2 = R_2\,/\omega\ /\ (1/C_2\omega\ -\ L_2\omega) = R_2C_2\omega\ /\ 1\text{-}L_2C_2\omega^2 \qquad (3)$$

Under these conditions, as mentioned hereinbefore, there will be oscillation if $\varphi_2 = -\varphi_1$ or $t_g\varphi_2 = -t_g\varphi_1$, viz. from the equation (3):

$$R_2C_2\omega\ /1\text{-}L_2C_2\omega^2 = -t_g\varphi_1 \qquad (4)$$

Figure 3 shows the variation of the value of $t_g\varphi_1$ as a function of the value of ω which represents the vibration frequency, to within the value of 2π (ω=2πN).

It will be noted that, without handpiece, the load of the oscillator in the work circuit is reduced to the value of the inductance Ls arranged in parallel between the output terminals S_1 and S_2 of the circuit. Furthermore, if R_s designates the internal resistance of the oscillator, the phase-shift of the current I_1 with respect to V_s is expressed by the expression:

$$t_{g\varphi} = L_s/R_s$$

The condition of oscillation $tg\varphi_2 = -tg\varphi_1$ then becomes:

$$R_2C_2\omega\ /\ (1\text{-}L_2C_2\omega^2) = -L_s\omega_s/R_s$$

or $\omega^2 = (L_s+R_sR_2C_2) / (L_sL_2C_2)$ (5)

By playing on the values of L_2 of the winding of the secondary 11 of the transformer T_2 and/or the value C_2 of the capacitor 13, the frequency of the oscillator may be adjusted off-load so that the synchronization curve shown in Figure 3 is modified.

In practice, R_2 represents the parasitic resistances of the circuit and C_2 will be conserved constant.

For each apparatus of a given series, it will then suffice to vary the value L_2 of the secondary 11 of the transformer T_2 until the voltage T_1 is in phase with the current I_1 circulating in the circuit.

The apparatus will then be calibrated and the oscillator will "lock" on the inductive delay load L_s.

Furthermore, as shown in Figure 4, a curve is available, which represents the variation of the power at the terminals E1, E2 of the handpiece 5, as well as the value of the phase-shift between current and intensity at the terminals thereof. Each type of handpiece 5 provided with a determined tool will thus have a curve of this type.

In the example of Figure 4, it will be observed that the power is maximum and the phase-shift is zero for a frequency of around 30 kHz. This value plotted at point X in the diagram of Figure 3 shows that the adjustment of the RLC circuit is correct since the value of $tg\varphi_1$ for this frequency is close to 0.

It is, of course, known that, during operation of the handpiece, the value of the frequency for which a maximum vibration with zero phase-shift is obtained,

varies as a function, on the one hand, of the physical nature of the handpiece but also as a function of the surface state of the material to be treated. For a handpiece and a given tool, two extreme frequences N_1 and N_2 will therefore be obtained, corresponding to the tool working on soft tissues and harder elements, to which values X_1 and X_2 of ω will correspond, as shown in Figure 3.

It has been observed that, in general, the frequency N lay at about 30 kHz. Under these conditions, an off-load adjustment of each circuit produced will be proceeded with (by adjusting the value of L_2 for example) so that, during work, points X_1 and X_2 indeed lie within zones for which tg_1 is close to zero, as shown in Figure 3.

The variation of the inductance L_2 may in particular be obtained by displacing a core at the centre of the self-induction coil 11.